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Developing LCFS for Biofuels: Getting it right for Corn Ethanol

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Topics

- **Purpose of LCFS**
- **Deployment timeframes for both biofuels and LCFS**
- **Importance of getting it right for corn-ethanol**
- **Biofuel Energy Systems Simulator**

Purpose of LCFS

- **2007 Energy Independence and Security Act (EISA)**
  - **Help guide R&D prioritization & investment**
- **CA Low Carbon Fuel Standard**
  - **Achieve a 10% reduction in motor fuel GHG intensity by 2020**
- **Foster and reward the build-out of a “green” biofuel industry**
  - **GHG emissions trading, certification**

2007 EISA definition: Life Cycle GHG Emissions

''(H) LIFECYCLE GREENHOUSE GAS EMISSIONS.—The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential.

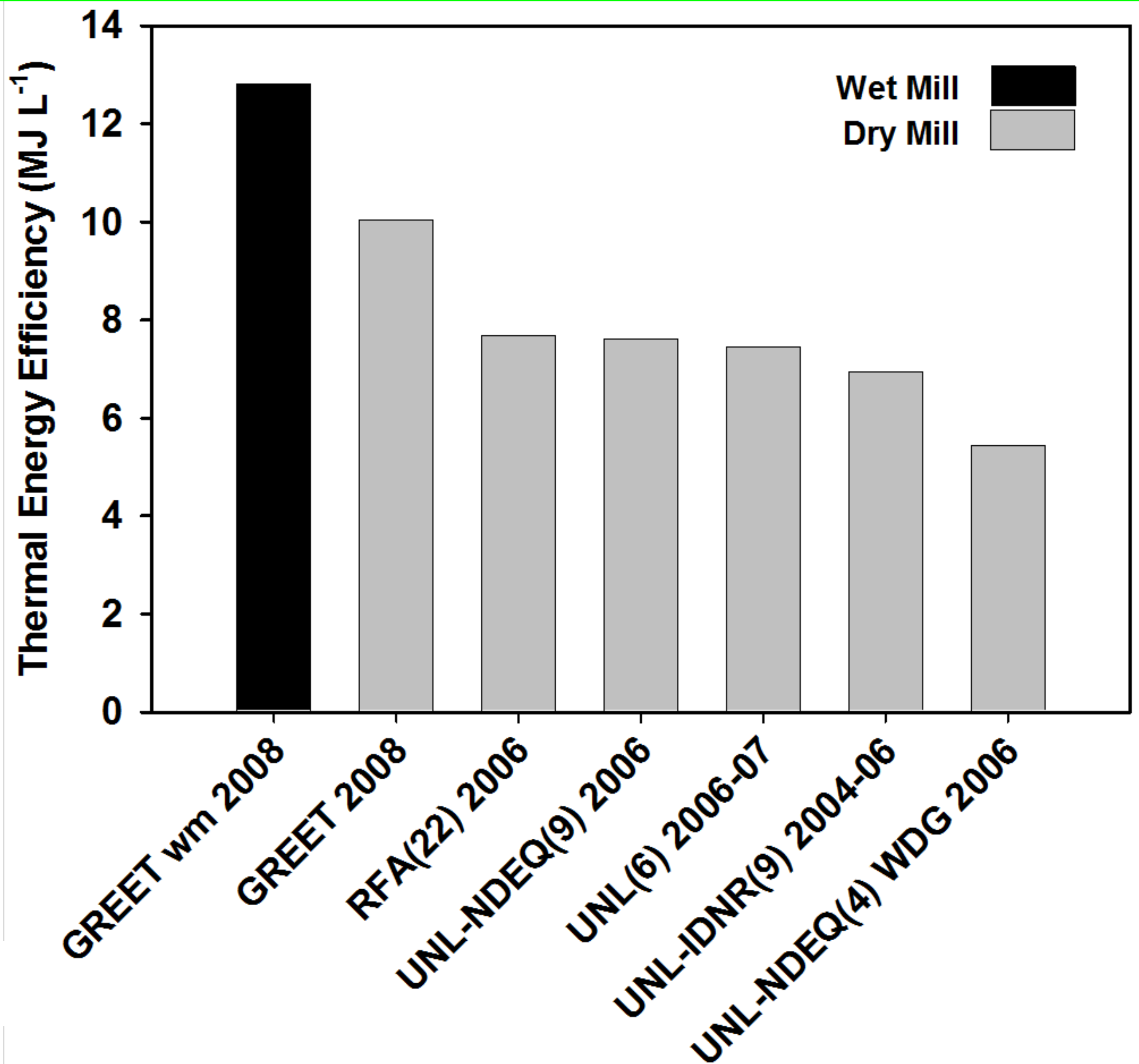
EPA Life Cycle Assessment Approach

- Domestic (FAPSOM) and international (FAPRI) agricultural sector models
  - Estimates land-use change in USA and globally
- GHG emissions derived from GREET and IPCC defaults
  - GREET includes carbon intensities for all petroleum-based and bio-based fuels

Need to get corn-ethanol right

- Rapid expansion of production capacity
- Actual data can be obtained for direct effects from crop production, ethanol conversion, and co-product use
  - Important to use values consistent with how the industry currently functions

Biorefinery thermal energy efficiency: Previous natural gas estimates vs. RFA & UNL surveys, NE & IA state records



Need to get corn-ethanol right

- Rapid expansion of production capacity
- Actual data can be obtained for direct effects from crop production, ethanol conversion, and co-product use
  - Important to use values consistent with how the industry currently functions
- Indirect effects difficult to estimate and highly uncertain
  - At what volume of production (15, 18, or 30 bgy?)
  - Currency exchange rates, land use policies, rate of yield gains on existing land?

2007 EISA renewable fuel standard mandate

YEAR	STARCH ETHANOL	ADVANCED BIOFUEL	TOTAL BIOFUEL
2008	9.0		9.0
2009	10.5	0.6	11.1
2010	12.0	1.0	13.0
2011	12.7	1.3	14.0
2012	13.2	2.0	15.2
2013	13.9	2.7	16.6
2014	14.4	3.8	18.2
2015	15.0	5.5	20.5
2018	15.0	11.0	26.0
2022	15.0	21.0	36.0

Corn-ethanol GHG emissions from different life-cycle models

Life-cycle GHG emissions intensity from dry-mill corn-ethanol (gCO2e/MJ)					
Emissions	**GREET**	**EBAMM**	**BEACCON**	**BESS (1)**	**BESS (5)**
Crop	**44**	**37**	**44**	**30**	**33**
Biorefinery	**43**	**64**	**37**	**31**	**25**
CP CREDIT	**-17**	**-25**	**-17**	**-19**	**-24**
Denaturant	**-**	**-**	**6**	**-**	**-**
Land use change	**(*104*)**	**-**	**1**	**-**	**-**
GWI	**70**	**76**	**71**	**43**	**35**
Gasoline	**92**	**92**	**92**	**92**	**92**
GHG reduction, %	**24**	**17**	**23**	**54**	**62**

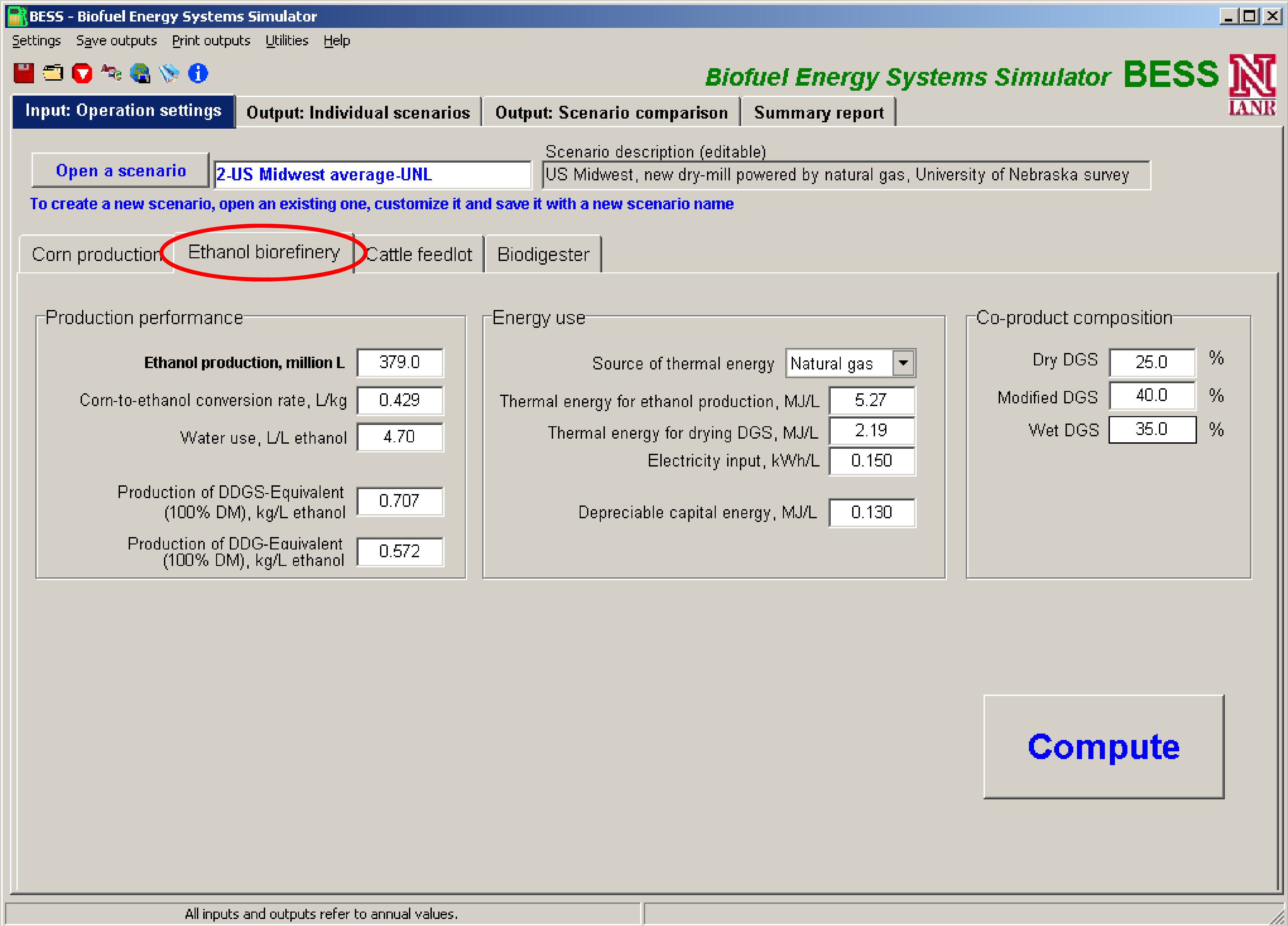
GREET vs.1.8a: land use change from Searchinger et al. Science 2008
EBAMM: vs.1.1-1: Farrell et al. 2006, Science, "Ethanol Today" avg. ethanol plant in 2001
BEACCON vs.1.1: available from www.lifecycleassociates.com; largely based on GREET
BESS: vs.2008.3.0: Scenario-1 Midwest avg. natl gas dry mill (RFA); Scenario-5 NE avg. natl gas with wet DGS
BESS has a variable co-product credit which is dependent on the emissions intensity of crop production

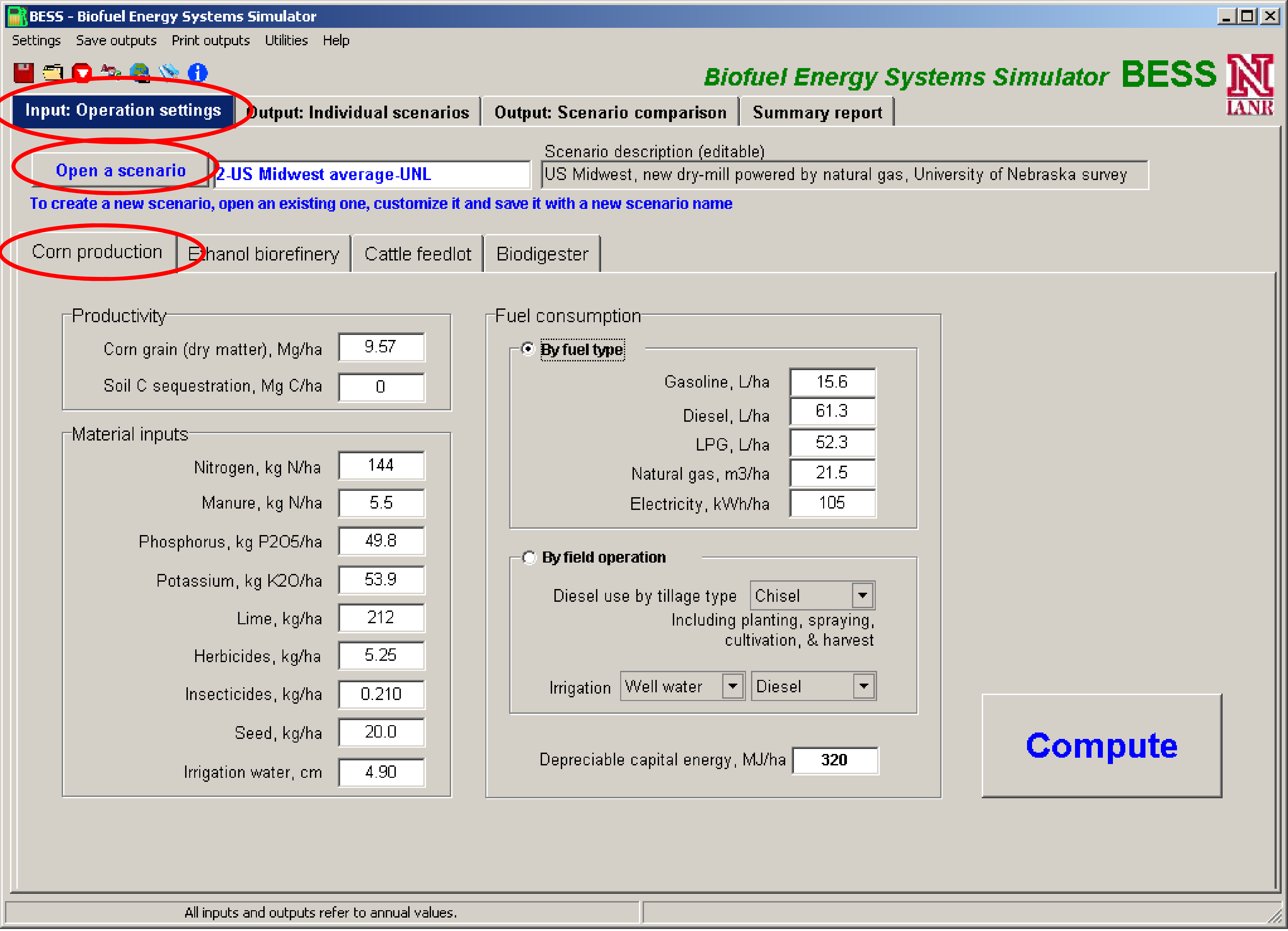
Biofuel Energy Systems Simulator (BESS)
www.bess.unl.edu

- **Most up to date estimates for direct-effect GHG emissions for corn ethanol based on best current science and input from all key disciplines (engineers, agronomists, soil scientists, animal nutritionists, industry professionals)**
- **User-friendly, completely transparent, and well documented**
- **Default scenarios based on regional-scale data, but can also be used for certification of an individual ethanol plant, its associated corn supply and co-product use**
- **Can be used for estimating carbon-offset credits for emissions trading with an individual ethanol plant as the aggregator**
- **If GREET can be consistent with BESS for corn-ethanol GHG emissions estimates, then BESS can be used for compliance and certification**

Default scenarios in BESS model: for different cropping regions and biorefinery types

Scenario #	Crop production region	Biorefinery energy (dry mill)	Co-product type	NEW Survey Data
1	USA Midwest Avg.	natural gas-MW	mix dry-wet DGS	RFA-22
2	USA Midwest Avg.	natural gas-MW	mix dry-wet DGS	UNL-6
3	Iowa Avg.	natural gas-IA	mix dry-wet DGS	IDNR-9
4	Nebraska Avg.	natural gas-NE	mix dry-wet DGS	NDEQ-9
5	Nebraska Avg.	natural gas-NE	Wet DGS	NDEQ-4
6	Nebraska Avg.	NG, closed-loop	Wet DG	NDEQ-4
7	Nebraska Avg.	coal	Dry DGS	EPA
8	Progressive cropping (CSP)	natural gas-NE	mix dry-wet DGS	NDEQ-9


BESS - Biofuel Energy Systems Simulator
Settings
Save outputs
Print outputs
Utilities
Help
Biofuel Energy Systems Simulator BESS
LANR
Input: Operation settings
Output: Individual scenarios
Output: Scenario comparison
Summary report
Open a scenario
2-US Midwest average-UNL
Scenario description (editable)
US Midwest, new dry-mill powered by natural gas, University of Nebraska survey
To create a new scenario, open an existing one, customize it and save it with a new scenario name
Corn production
Ethanol biorefinery
Cattle feedlot
Biodigester
Production performance
Ethanol production, million L
379.0
Corn-to-ethanol conversion rate, L/kg
0.429
Water use, L/L ethanol
4.70
Production of DDGS-Equivalent (100% DM), kg/L ethanol
0.707
Production of DDG-Equivalent (100% DM), kg/L ethanol
0.572
Energy use
Source of thermal energy
Natural gas
Thermal energy for ethanol production, MJ/L
5.27
Thermal energy for drying DGS, MJ/L
2.19
Electricity input, kWh/L
0.150
Depreciable capital energy, MJ/L
0.130
Co-product composition
Dry DGS
25.0
%
Modified DGS
40.0
%
Wet DGS
35.0
%
Compute
All inputs and outputs refer to annual values.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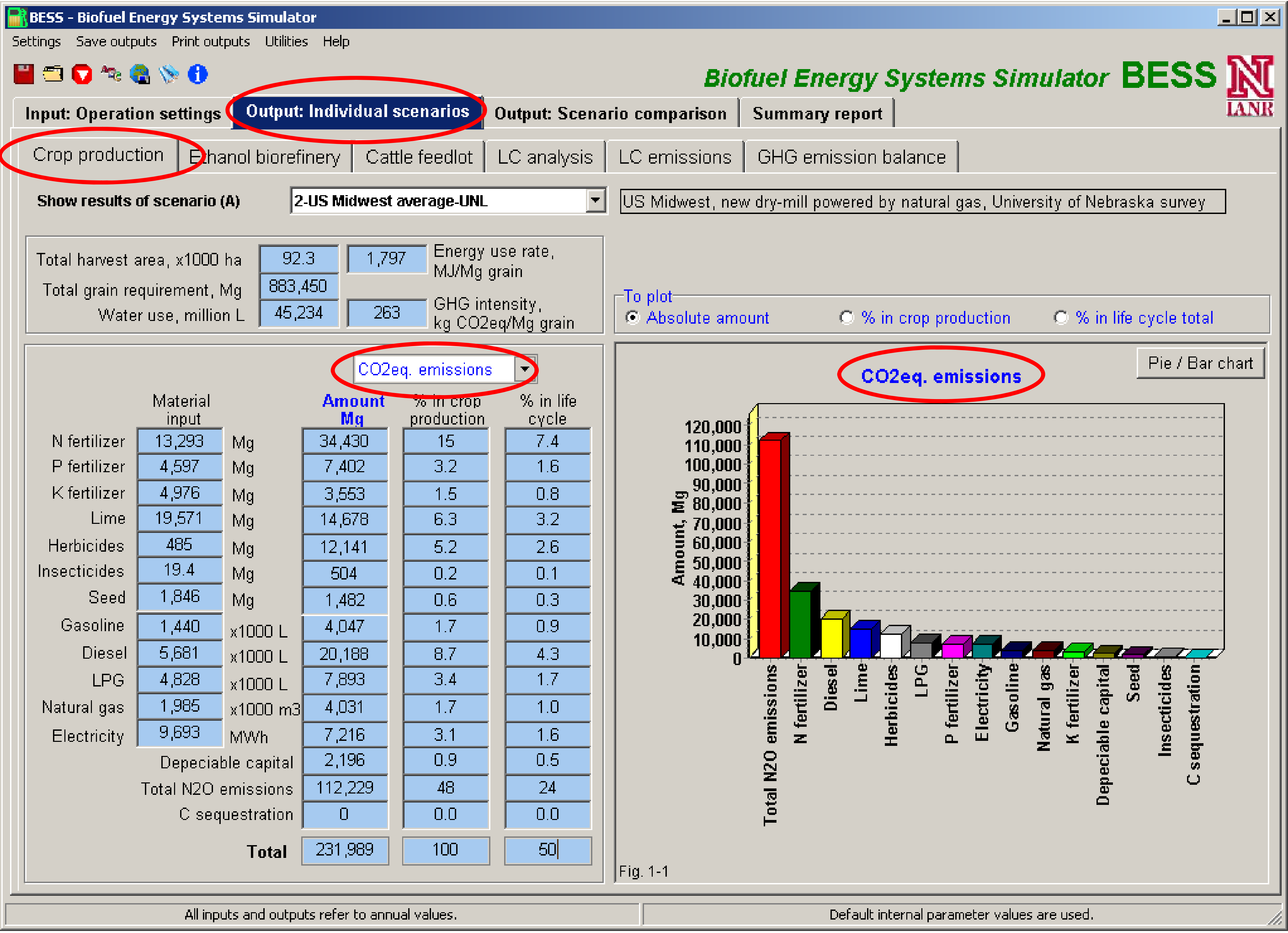
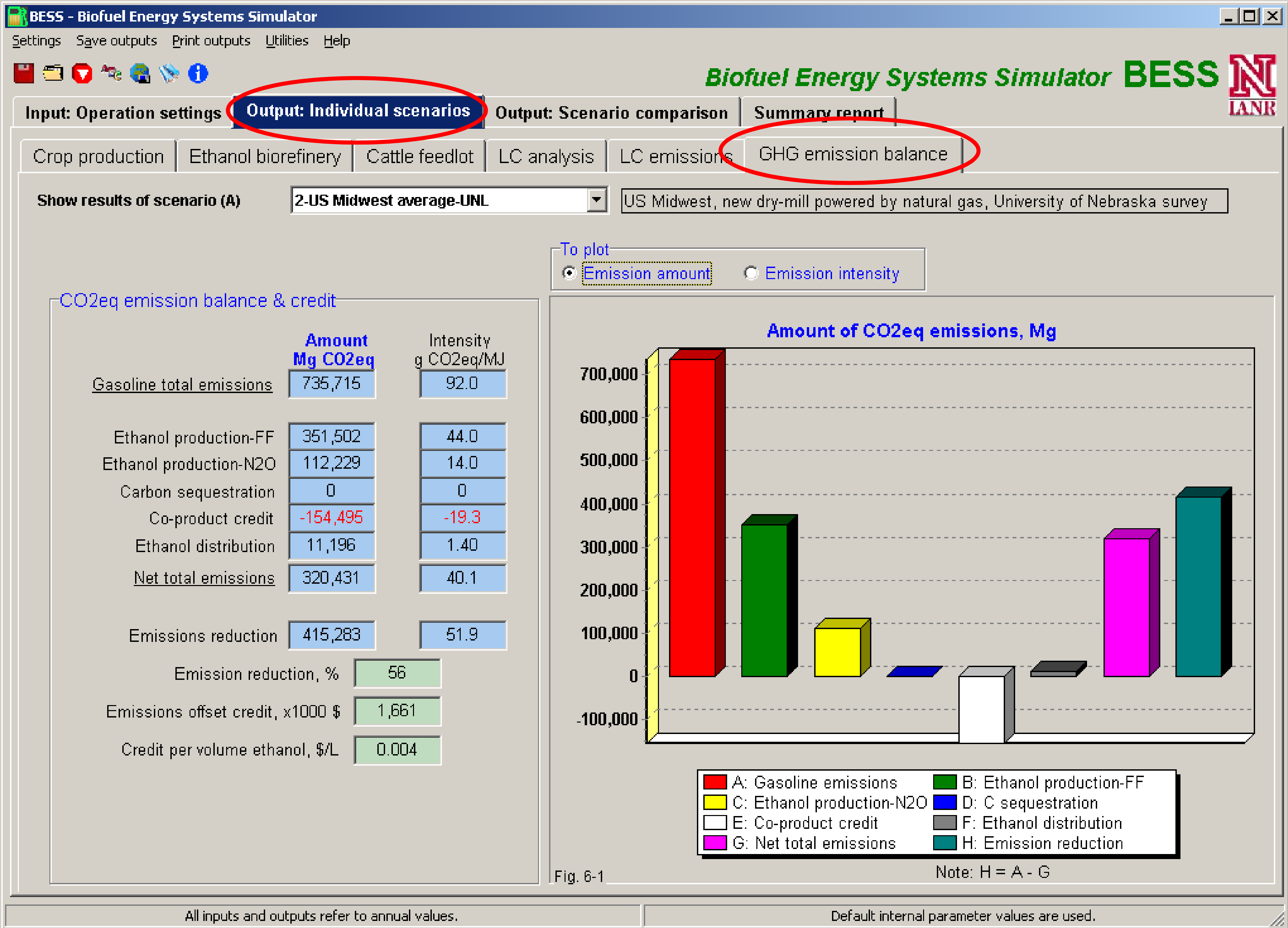
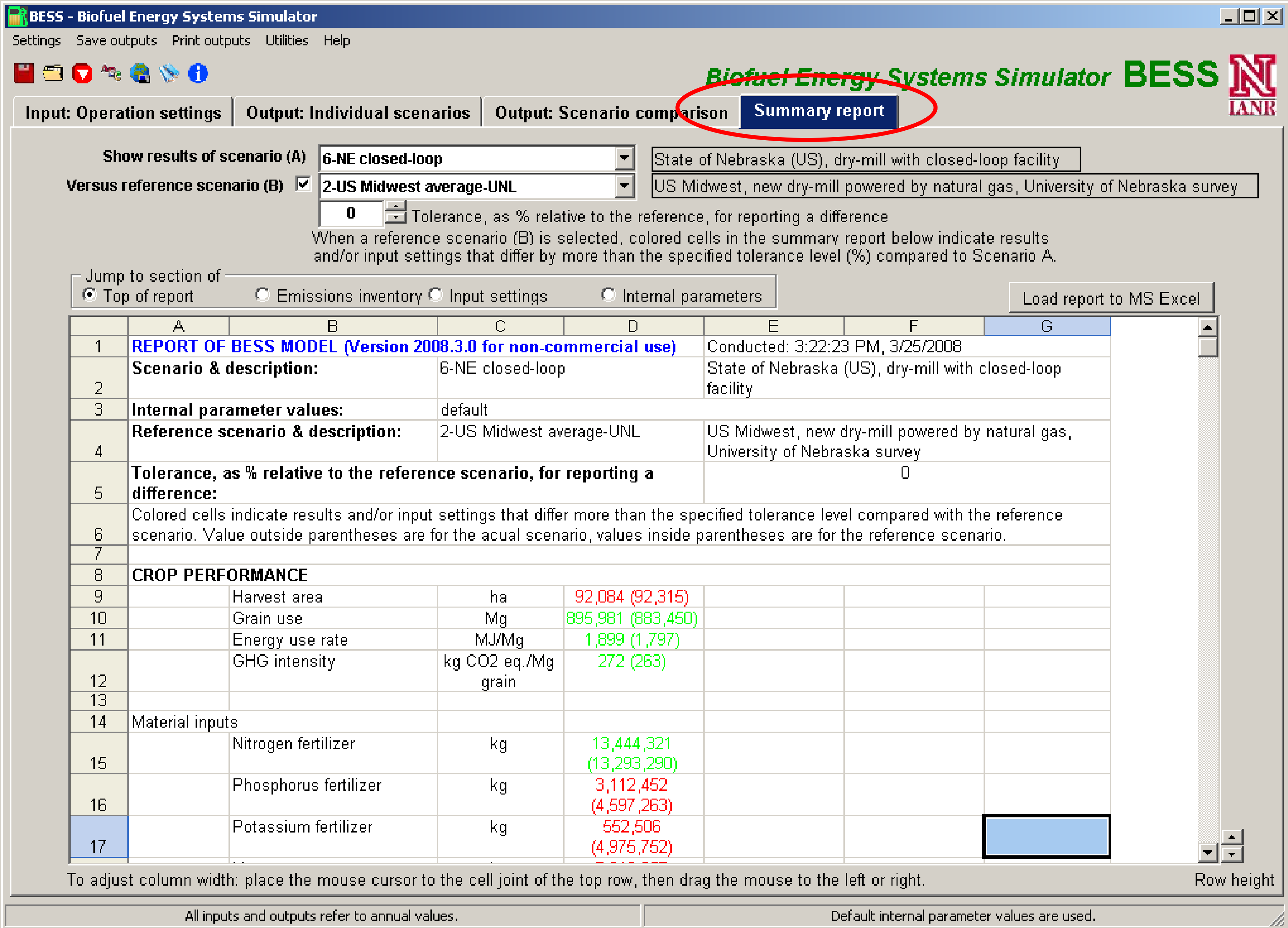
Output: Scenario comparison
Summary report
Open a scenario
2-US Midwest average-UNL
Scenario description (editable)
US Midwest, new dry-mill powered by natural gas, University of Nebraska survey
To create a new scenario, open an existing one, customize it and save it with a new scenario name
Corn production
Ethanol biorefinery
Cattle feedlot
Biodigester
Productivity
Corn grain (dry matter), Mg/ha 9.57
Soil C sequestration, Mg C/ha 0
Material inputs
Nitrogen, kg N/ha 144
Manure, kg N/ha 5.5
Phosphorus, kg P2O5/ha 49.8
Potassium, kg K2O/ha 53.9
Lime, kg/ha 212
Herbicides, kg/ha 5.25
Insecticides, kg/ha 0.210
Seed, kg/ha 20.0
Irrigation water, cm 4.90
Fuel consumption
By fuel type
Gasoline, L/ha 15.6
Diesel, L/ha 61.3
LPG, L/ha 52.3
Natural gas, m3/ha 21.5
Electricity, kWh/ha 105
By field operation
Diesel use by tillage type Chisel
Including planting, spraying, cultivation, & harvest
Irrigation Well water Diesel
Depreciable capital energy, MJ/ha 320
Compute
All inputs and outputs refer to annual values.



	Material input		Amount Mg	% in crop production	% in life cycle
N fertilizer	13,293	Mg	34,430	15	7.4
P fertilizer	4,597	Mg	7,402	3.2	1.6
K fertilizer	4,976	Mg	3,553	1.5	0.8
Lime	19,571	Mg	14,678	6.3	3.2
Herbicides	485	Mg	12,141	5.2	2.6
Insecticides	19.4	Mg	504	0.2	0.1
Seed	1,846	Mg	1,482	0.6	0.3
Gasoline	1,440	x1000 L	4,047	1.7	0.9
Diesel	5,681	x1000 L	20,188	8.7	4.3
LPG	4,828	x1000 L	7,893	3.4	1.7
Natural gas	1,985	x1000 m3	4,031	1.7	1.0
Electricity	9,693	MWh	7,216	3.1	1.6
Depeciable capital			2,196	0.9	0.5
Total N2O emissions			112,229	48	24
C sequestration			0	0.0	0.0
Total			231,989	100	50


BESS - Biofuel Energy Systems Simulator
Settings Save outputs Print outputs Utilities Help
Biofuel Energy Systems Simulator BESS
LANR
Input: Operation settings
Output: Individual scenarios
Output: Scenario comparison
Summary report
Crop production
Ethanol biorefinery
Cattle feedlot
LC analysis
LC emissions
GHG emission balance
Show results of scenario (A)
2-US Midwest average-UNL
US Midwest, new dry-mill powered by natural gas, University of Nebraska survey
To plot
Emission amount
Emission intensity
CO2eq emission balance & credit
Amount Mg CO2eq
Intensity g CO2eq/MJ
Gasoline total emissions 735,715 92.0
Ethanol production-FF 351,502 44.0
Ethanol production-N2O 112,229 14.0
Carbon sequestration 0 0
Co-product credit -154,495 -19.3
Ethanol distribution 11,196 1.40
Net total emissions 320,431 40.1
Emissions reduction 415,283 51.9
Emission reduction, % 56
Emissions offset credit, x1000 $ 1,661
Credit per volume ethanol, $/L 0.004
Amount of CO2eq emissions, Mg
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
-100,000
A: Gasoline emissions
B: Ethanol production-FF
C: Ethanol production-N2O
D: C sequestration
E: Co-product credit
F: Ethanol distribution
G: Net total emissions
H: Emission reduction
Fig. 6-1
Note: H = A - G
All inputs and outputs refer to annual values.
Default internal parameter values are used.


BESS - Biofuel Energy Systems Simulator
Settings
Save outputs
Print outputs
Utilities
Help
Biofuel Energy Systems Simulator BESS
LANR
Input: Operation settings
Output: Individual scenarios
Output: Scenario comparison
Summary report
Show results of scenario (A)
6-NE closed-loop
State of Nebraska (US), dry-mill with closed-loop facility
Versus reference scenario (B)
2-US Midwest average-UNL
US Midwest, new dry-mill powered by natural gas, University of Nebraska survey
0
Tolerance, as % relative to the reference, for reporting a difference
When a reference scenario (B) is selected, colored cells in the summary report below indicate results and/or input settings that differ by more than the specified tolerance level (%) compared to Scenario A.
Jump to section of
Top of report
Emissions inventory
Input settings
Internal parameters
Load report to MS Excel
A B C D E F G
1 REPORT OF BESS MODEL (Version 2008.3.0 for non-commercial use) Conducted: 3:22:23 PM, 3/25/2008
2 Scenario & description: 6-NE closed-loop State of Nebraska (US), dry-mill with closed-loop facility
3 Internal parameter values: default
4 Reference scenario & description: 2-US Midwest average-UNL US Midwest, new dry-mill powered by natural gas, University of Nebraska survey
5 Tolerance, as % relative to the reference scenario, for reporting a difference: 0
6 Colored cells indicate results and/or input settings that differ more than the specified tolerance level compared with the reference scenario. Value outside parentheses are for the acual scenario, values inside parentheses are for the reference scenario.
7
8 CROP PERFORMANCE
9 Harvest area ha 92,084 (92,315)
10 Grain use Mg 895,981 (883,450)
11 Energy use rate MJ/Mg 1,899 (1,797)
12 GHG intensity kg CO2 eq./Mg grain 272 (263)
13
14 Material inputs
15 Nitrogen fertilizer kg 13,444,321 (13,293,290)
16 Phosphorus fertilizer kg 3,112,452 (4,597,263)
17 Potassium fertilizer kg 552,506 (4,975,752)
To adjust column width: place the mouse cursor to the cell joint of the top row, then drag the mouse to the left or right.
Row height
All inputs and outputs refer to annual values.
Default internal parameter values are used.

Influence of cropping system and biorefinery type on GHG emissions reduction: %, Mg CO2e*

20% reduction for 2007 EISA RFS

Corn Production System

Ethanol Biorefineries

	USA-MW average	Iowa average	NE average	Advanced Irrigated
coal	24%, 179,000	26%, 187,000	21%, 153,000	25%, 186,000
natural gas†	**54%, 395,000**	**57%, 420,000**	**50%, 371,000**	55%, 405,000
natural gas, wet DG	64%, 469,000	64%, 468,000	**62%, 444,000**	64%, 474,000
closed-loop facility	72%, 526,000	72%, 529,000	68%, 498,000	73%, 534,000

*Based on a 100 million gal yr-1 production capacity, †average based on surveys

BESS model results, vers. 2008.3.0, **www.bess.unl.edu**

Our recommendation to California Air Resources Board: Create 3 classes of ethanol facilities for GHG regulation

1) Title V permitted facilities; major source, e.g. 100 tons VOC/yr (includes all wet mills and coal powered facilities in Nebraska and Iowa, 9 out of 31 facilities in 2006)

2) Dry mills powered by natural gas (largest group)

3) Dry mills powered by natural gas, without dryers for DG (e.g. high cattle densities, closed-loop facilities, DG as energy source)

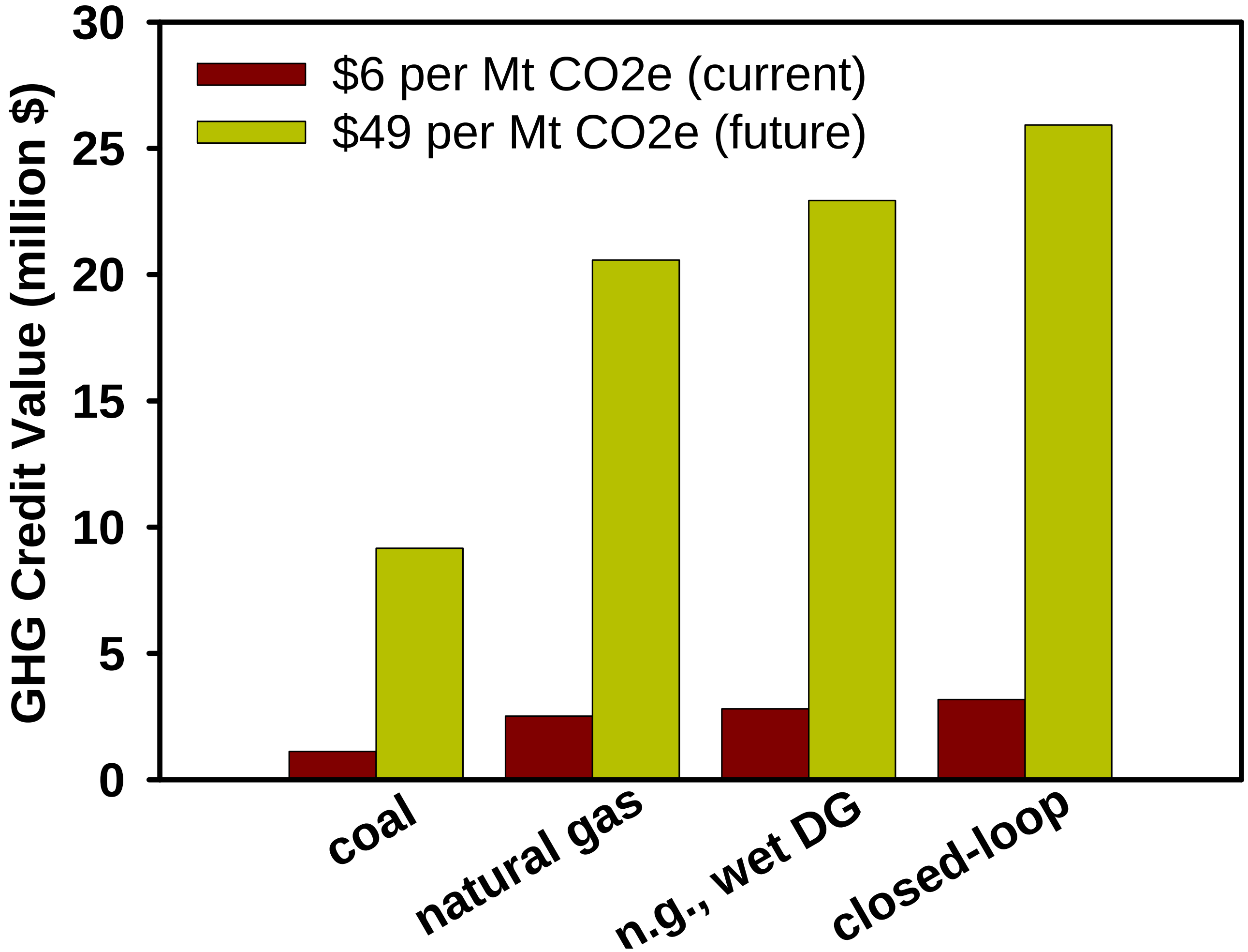
Class	I	II	III
Description	Title V (coal with Dry DG)	Natural Gas Dry Mills	N.G. Dry Mills w/ Wet DG
Thermal Energy, MJ L-1	12.81	7.61	5.44
BESS Life-cycle GHG emissions reduction	7%	51%	62%

GHG emissions trading credit (cap-and-trade) for ethanol biorefineries according to type

Current European price* April 15, 2008

€25 per Mt
or
$40 per Mt

At future price
~$0.23 per gallon



*www.pointcarbon.com; Chart results based on a 100 million gal yr-1 production capacity in IA; $6 per metric ton CO2e, Apr. 15.2008, Chicago Climate Exchange, www.chicagoclimatex.com/ Future carbon price of $49 per metric ton CO2e, pending ***Climate Security Act of 2007*** (Kintisch 2007); BESS.2008.3.0, www.bess.unl.edu

Sensitivity of input parameters on corn-ethanol carbon intensity:

The three most influential input parameters:

1. crop yield: Mg per hectare (+25% possible)
2. conversion thermal energy inputs: MJ per liter (+10%)
3. conversion yield: liters ethanol per kg grain (+7%)

Next in importance:

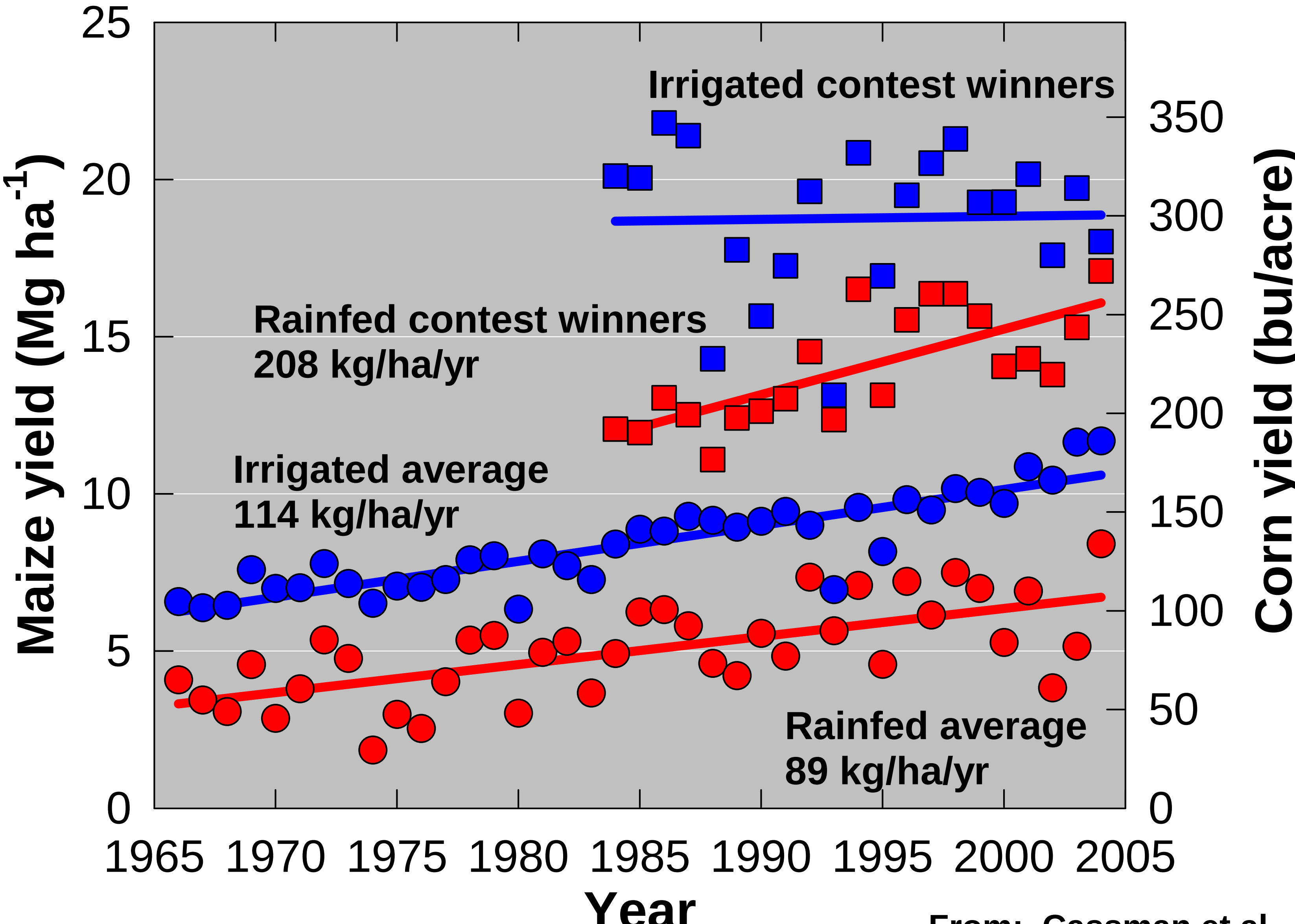
-wet versus drying distiller's grains
-N fertilizer rate used in crop production

How to deal with indirect effects of land use change?

- **One value for carbon "debt" from LUC applied to all USA corn-ethanol**
- **Key issues are:**
  - **Direct-effect GHG emissions starting point (50-65% reduction as estimated by BESS, or 24% as estimated by GREET in Searchinger et al (*Science*, 2008)**
  - **Volume of corn-ethanol production modeled by FAPRI/FASOM to estimate magnitude of land use change**
  - **Assumptions about rate of gain in corn yields**
- **What if there was a focused program to accelerate the rate of gain in corn yields while reducing GHG emissions per bushel produced?**
  - **A process called ecological intensification (*PNAS*, 1999)**

Nebraska contest-winning vs average yield trends

Average yields are only about 60% of yield potential!



From: Cassman et al., 2003

CONCLUDING REMARKS

- Corn ethanol will be first to test the newly developed LCFS assessment methods; substantial amounts of other biofuels will come several years later
- Accurate valuation of direct-effect GHG emissions from corn ethanol is the foundation of the LCFS process; these affects vary with ethanol biorefinery type and corn feedstock supply
- Different reference GHG emissions values are needed for each major class of ethanol plants
- The BESS model provides the most up-to-date, scientifically sound estimate of corn-ethanol GHG emissions; can BESS and GREET reach agreement?
- Certification and compliance tools are also needed

Funding Support for BESS Development

- Western Governor's Association & US DOE
- Environmental Defense
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- Nebraska Energy Office
- Nebraska Center for Energy Sciences Research

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Professor Dick Perrin, UNL Ag. Economics

FREE download of BESS model: www.bess.unl.edu

- BESS model for CELLULOSIC ETHANOL from Corn residue and switchgrass, *Summer 2008*

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